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Technical Report 057

EVALUATION OF CONDENSATE RETURN LINE CORROSION TESTERS

13 March 1961

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U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

EVALUATION OF CONDENSATE RETURN LINE CORROSION TESTERS

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Type B Final Report

by

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OBJECT OF TASK

To comparatively evaluate three methods for detecting internal corrosion in steam condensate return pipes as to accuracy, dependability and relative lengths of time and operations involved in making measurements.

ABSTRACT

Three proprietary testers were evaluated: the National District Heating Association Corrosion Tester, the Bureau of Mines Condensate-Corrosion Tester, and the Crest Instrument Company Corrosometer probe. An NCEL tester was also evaluated.

In two laboratory and two field test series, the variation in the test data was relatively insignificant among three testers - the BuMines tester, the Corrosometer probe and the NCEL tester. The NDHA tester showed a significant variation in the test data from the other testers.

INTRODUCTION

Corrosion in steam condensate pipelines of steam-heating and steam power plants is a constant problem throughout the Naval Shore Establishment. Maintenance and repair costs have been estimated at $2,500,000 for the first six months of 1955 in continental United States installations of one of the defense agencies.[1] Early detection and prevention of corrosion is therefore of the utmost importance.

The devices most commonly used at naval installations for detecting internal pipe corrosion are the National District Heating Association (NDHA) Corrosion Tester and the Bureau of Mines (BuMines) Condensate-Corrosion Tester. Although these testers are generally accepted as reliable, they require a minimum of 30 days to show the amount of corrosion. Another device, the Corrosometer probe introduced several years ago by National Aluminate Corporation, is advertised as needing a minimum of time to determine the amount and rate of corrosion. BuDocks therefore requested that NCEL undertake an evaluation and comparison of these three methods for detecting corrosion in internal condensate return lines. In addition, a tester was fabricated by the Laboratory.

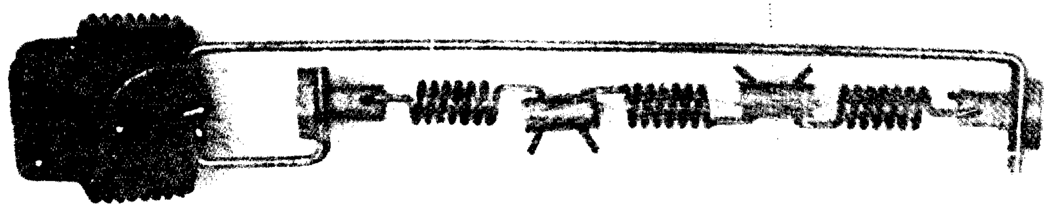
CORROSION TESTERS

BuMines Tester

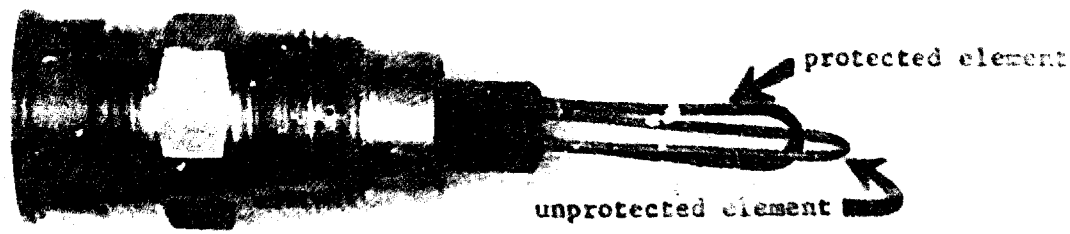
The BuMines Condensate-Corrosion Tester was developed by the Industrial Water Laboratory, Bureau of Mines, Department of the Interior, at College Park, Maryland. The tester consists of a 3/4-inch-diameter by 3-inch-long pipe nipple, which accommodates six carefully weighed and measured internal steel rings. The amount of corrosion is determined by the loss in weight by corrosion of the rings. This composite nipple is mounted between two conventional pipe couplings and two additional pipe nipples, forming a corrosion test unit as illustrated in Figure 1.

The Industrial Water Laboratory recommends installation of these testers at a point somewhat removed from the steam boiler plant and downstream from an active condensate trap which is draining a unit heater or other condensing unit. In plants having a history of corrosion, tests of from 60 to 90 days are recommended, though longer test periods are common in plants having relatively few maintenance problems.

A - BuMines Condensate-Corrosion Tester



B - Dearborn Chemical Co., NDHA Corrosion Tester



C - Crest Instrument Co., Corrosometer Probe

D - NCEL Coupon Tester

Figure 1. Corrosion testers evaluated.

At the conclusion of the test exposure period, the testers are returned to the Industrial Water Laboratory for evaluation. The rings are removed and cleaned by special processes, then reweighed to determine weight loss and given a critical examination. As a result of the examination and evaluation, the Industrial Water Laboratory is able to determine the rate and amount of corrosion in the condensate return line sampled. In addition to indicating the degree of corrosion, the tester shows a corrosion pattern by the pitting, channeling and worming, thereby providing a guide to the causes of the corrosion.

NDHA Tester

The NDHA Corrosion Tester (obtained through the Dearborn Chemical Company, Chicago, Illinois) represents one of the original efforts toward development of a test instrument to determine which steam plants could benefit by the chemical treatment of condensate.[1] This tester utilizes the same principle as the BuMines tester, but uses steel coils rather than rings. The unit consists of three helical coils of wire mounted on, but insulated from, a steel frame attached to a standard pipe plug, as shown in Figure 1. Wire coils for these testers are available in a variety of materials such as aluminum, brass, copper and nickel, as well as Bessemer steel which is usually used in steam condensate return-line tests.

Installation and exposure time recommendations for the NDHA tester are similar to those of the Industrial Water Laboratory for their tester. Test units are returned to the manufacturer for evaluation after the exposure period. Corrosion rate and magnitude are determined by a comparison with recorded original weights and by the application of a constant determined for the coil material. Frames are re-usable and individual coils are available for local weighing and analysis by the user.

Corrosometer Tester

The Crest Corrosometer and Corrosometer probes, available through the Crest Instrument Company, Santa Fe Springs, California, utilizes the principle that metals have a high electrical conductivity. A special probe (Figure 1) with a protected and an unprotected element of the desired metal, is installed in the suspect pipeline. As corrosion of the unprotected element occurs, the subsequent greater electrical resistance increases the difference between the conductivity of the protected and unprotected elements. This is determined through the use of an electrical resistance bridge apparatus. Because the measurement is a ratio of the two resistances, it is independent of the current used to energize the bridge as well as of temperature change. Thirty probe materials are available in three different forms. The more sensitive forms are thin-walled tubes and wires. Strips are available for long-time use.

Corrosion loss is read directly from the dials of the electrical bridge test instrument while the test probe is undergoing exposure in the line. Successive readings should be plotted versus time, and corrosion trends determined graphically. Figure 2 presents a graph of the rate of corrosion during one of the test series. A straight-line relationship exists, with a slight increase in corrosion loss with time.

NCEL Coupon Tester

In addition to the three proprietary testers evaluated, coupons were cut from a section of a typical condensate return-line pipe and mounted in pipe plugs, as shown in Figure 1, for exposure in the various test series. The degree of corrosion was determined by the difference in the original weights of the coupons and the weights when cleaned after tests.

TESTS PERFORMED

Two laboratory exposure test series and two field test series were conducted with the four types of testers. For identification purposes the exposure series will be referred to as Laboratory-1 and Laboratory-2, Field-1 and Field-2.

In the Laboratory-1 test series, one corrosion tester of each type was installed in a plastic manifold in which a one-percent solution of HCl in water was circulated by a small pump. The testers were arranged in series and were subjected successively to the corrodent. This test series was not intended to simulate a steam condensate line but rather to compare the testers with equal quantities of a known corrodent continuously passing each tester.

In the Laboratory-2 test series, one of each of the proprietary testers was installed in each leg of the test manifold shown in Figure 3. A 3/4-inch-diameter by 3-inch-long pipe nipple was also installed in order to compare the results of the corrosion testers with the actual loss in a pipe section.

Prior to installation the nipple was cleaned and weighed, and at the conclusion of the test it was again cleaned and weighed and the corrosion loss was determined as the average loss over the interior surface. In this test series, condensate was "borrowed" from the NCEL steam plant return-line system and pumped through the manifold at a pressure of approximately 8 psi and a temperature of from 130 to 200 degrees Fahrenheit. Equal flow through each leg of the manifold was accomplished by adjusting the throttle valves on the discharge side and measuring the flow volumetrically for a given period of time. Each leg of the manifold was equipped with a swing joint in the pipe fittings discharging into the effluent collecting trough, as shown in Figure 3.

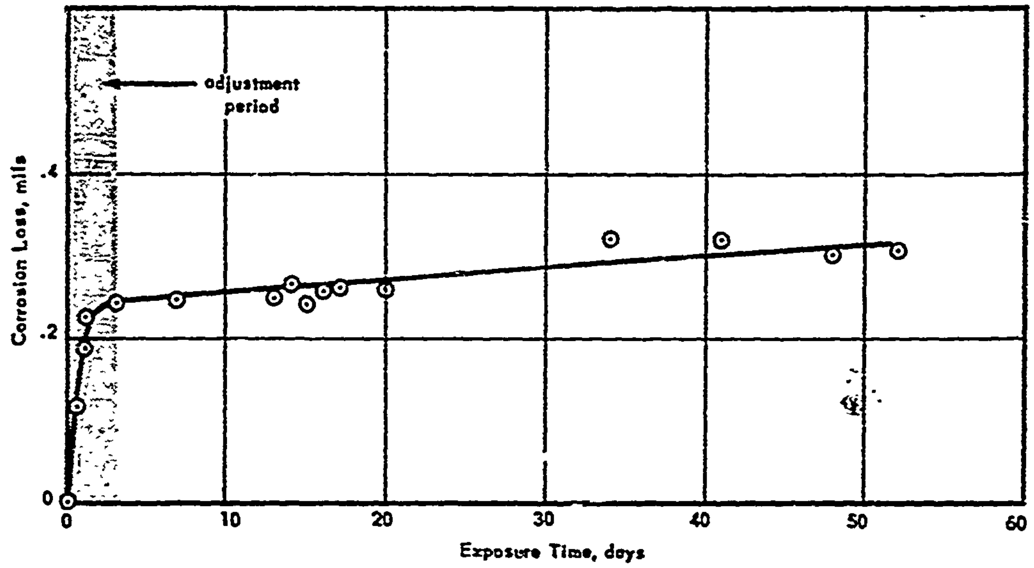


Figure 2. Corrosometer readings, Laboratory-2 test series.

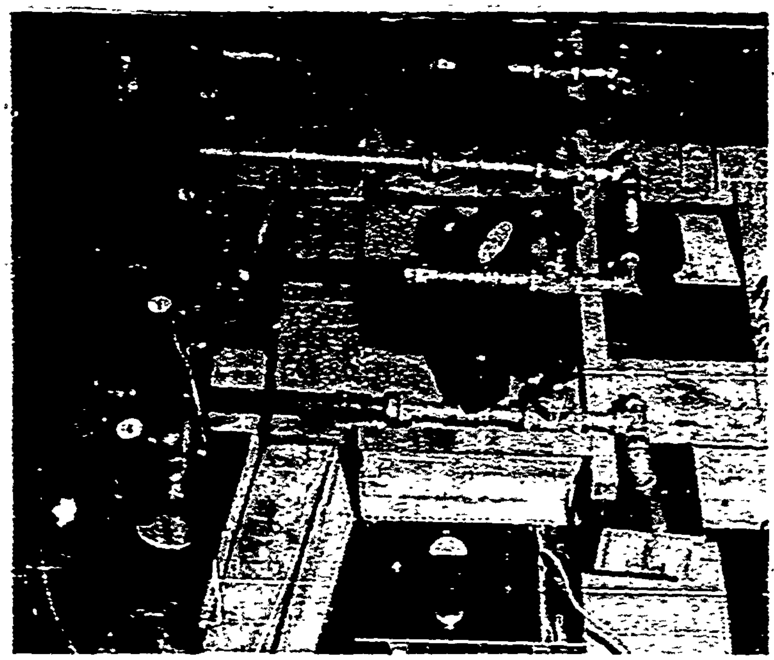


Figure 3. Test manifold used in Laboratory-2 test series. A - BuMines Tester; B - NDHA Tester; C - Corrosometer Probe; D - NCEL Coupon Tester.

Field-1 and Field-2 test series utilized test manifolds as shown in Figure 4, in which one corrosion tester of each type was installed. Three manifolds were prepared and installed in condensate lines of two separate steam systems at CBC, Port Hueneme, California. Two of the manifolds were installed in the Thomas system, which is the largest at CBC, Port Hueneme. In the past, this system has required very little maintenance due to condensate corrosion. One manifold was installed in the final fifty feet of the condensate return line and therefore was subjected to all the corrosive products of the entire condensate return system. The second manifold was installed in the final fifty feet of one of the subsystem branch lines and was subjected to approximately one-fifth of the system's total condensate return. Manifolds were bled after installation to make certain that they were filled. Design factors indicated that equal flow could be expected in each leg of the manifold. A pressure gage was installed in each leg to indicate full flow, and total steam production and makeup requirements were recorded for the test period. Results showed the two Thomas installations to have approximately the same amount of corrosion; they are therefore combined in the tabulation of results under "Thomas Boiler."

The third manifold was installed in the condensate return line of the Laboratory's steam system. Installation was similar to those in the Thomas system. This system requires considerable maintenance to offset condensate corrosion damage. Despite extensive water and condensate treatment and close supervision of operating practices, this condensate return system is corroding at a high rate, as shown in the test results and confirmed by actual maintenance requirements.

TEST RESULTS

Table I shows the numerical results of evaluation tests of the testers used in this investigation; Figure 5 is a graphic presentation. The variation in the test data was relatively insignificant among three testers - the BuMines tester, the Corrosometer probe and the NCEL tester. The NDHA tester showed a significant variation in the test data from the other testers.

DISCUSSION

All testers except the Corrosometer require from 30 to 60 days exposure to arrive at a corrosion indication; the length of exposure period is directly related to the corrosiveness of the condensate. A period of 10 days to 2 weeks lapses while the BuMines and NDHA testers are returned to the supplier for evaluation. This evaluation can be done by the user, but is not recommended. The NCEL testers were evaluated at the Laboratory within a few days.

Figure 4. Test manifold used in Field-1 and -2 test series. A - BuMines Tester; B - NDHA Tester; C - Corrosometer Probe; D - NCEL Coupon Tester.

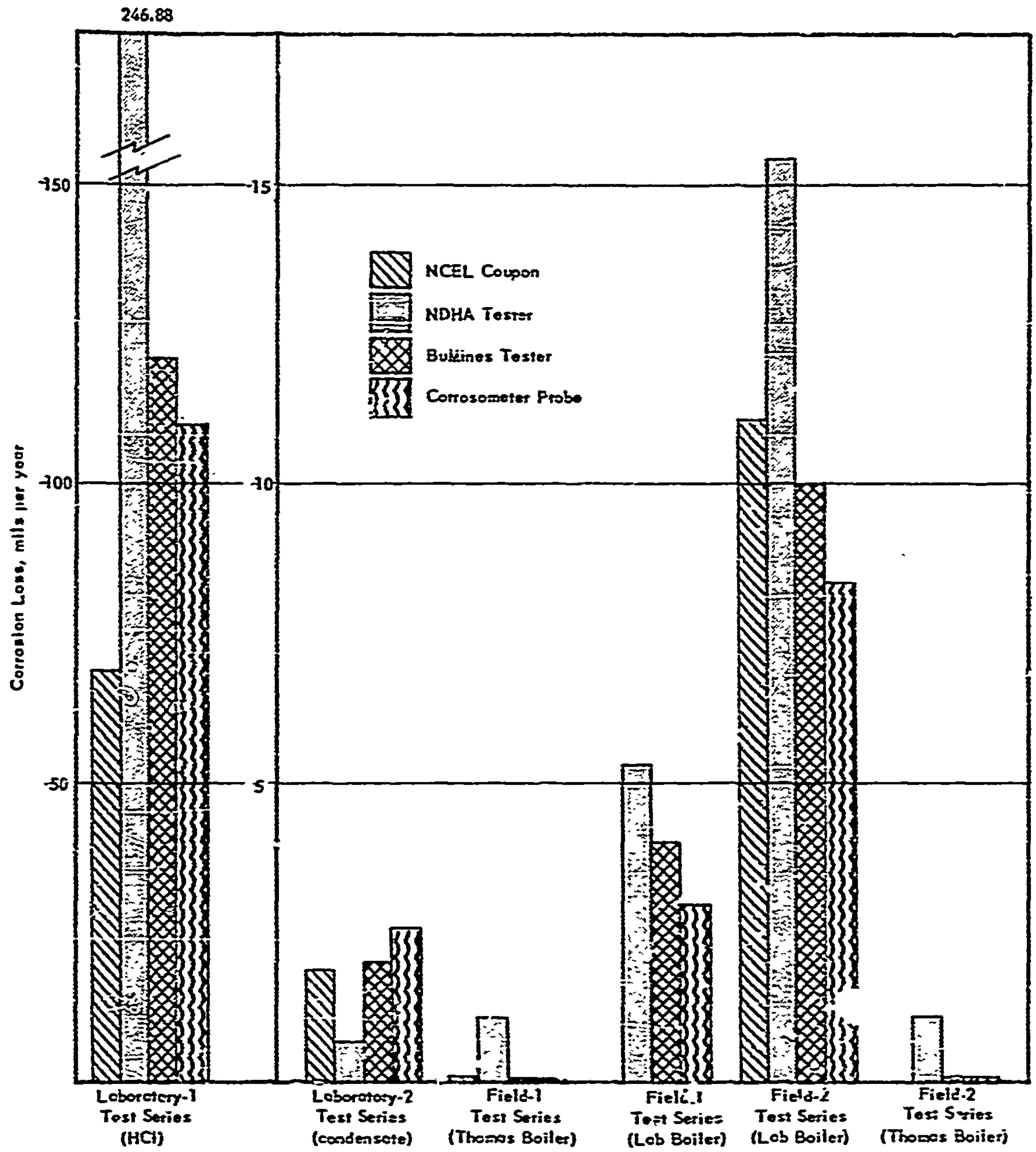


Figure 5. Pipe wall thickness loss in mils per year for corrosion testers.

Table I.

Total Annual Average Loss Expressed in Mils Thickness of Pipe Wall Loss .or Corrosion Testers

Test Series	Length of Test (days)	Location	NCEL Specimens[1]	NOHA[2]	BuMines[3]	Corrosometer[4]
Laboratory-1 (HCl)	6	Pilot Plant	68.26	246.88	121	109.07
Laboratory-2 (Condensate)	53	Laboratory	1.78	0.72	2	2.55
Field-1 (Condensate)	60	Thos Boiler[5]	0.03	1.05	0	0.00
		Lab Boiler	----	5.28	4	2.93
Field-2 (Condensate)	60	Thos Boiler[5]	----	0.76	0	0.00
		Lab Boiler	10.80	15.44	10	8.32

1. Pipe nipple in Laboratory-2 series; coupon in all other series; both of Bessemer steel.

2. Steel coils suitable for temperatures up to 225° F.

3. Bessemer steel.

4. General purpose probe, model 2022, with iron tube element.

5. Average of two.

About a week after the adjustment period is the minimum time for the Corrosometer to determine the degree of corrosion. It was found desirable, when installing a new Corrosometer probe, to allow 3 to 5 days for the probe to become adjusted; thereafter, progressive corrosion or the effect of inhibitors could readily be observed. This is illustrated in Figure 2.

The fact that many Corrosometer probes can be installed and that the amount of corrosion can be quickly determined without removing the probes are distinct advantages. In addition, the Corrosometer can detect as little as a tenth of a microinch of corrosion. This would permit fine adjustments of chemical treatment to be used and a solution to the corrosion problem to be determined in a matter of weeks rather than months.

The out-of-pocket cost of the testers is another factor to be considered along with time and dependability in the selection of a corrosion determination method. With the exception of the Corrosometer, the cost of testers is small. The BuMines tester is furnished to US naval activities at no cost. This includes evaluation of exposed testers and a report of the findings and recommendations to the user. NDHA testers are available from various suppliers, such as the Dearborn Chemical Company, for $10.00 f.o.b. the factory. The charge includes subsequent evaluation and a report of the findings to the user. Costs for coupon and pipe nipple specimens such as those prepared by NCEL are less significant since they can be fabricated by local station forces; however, facilities required for evaluating these specimens may preclude the use of this tester.

The Corrosometer electrical resistance bridge and probes, on the other hand, represents a large investment. The Crest Instrument Company lists the current Model CK (similar to that used by the Laboratory in this investigation) at $650.00. Probes cost from $50.00 to $250.00, depending upon the material used and the physical requirements necessary to withstand various pressures and temperatures. Probe elements are available for replacing exposed elements at prices up to 75 percent of the complete probe (from $30 to $85). This high cost could preclude the use of instruments of this type on an individual station basis; however, it might be feasible for District Offices or Public Works Centers to purchase such an instrument for use on a rotational or need basis for individual stations under their cognizance.

In order to find out what testers were actually in use in the field, information was obtained from all District Public Works Officers. It was found that the commercial testers evaluated were in use in the Districts. In addition, several other testers were mentioned. These were test specimens furnished by Hall Laboratories, Division of Hogan Chemicals and Controls, Inc.; Betz Laboratories; and Wright Chemical Corporation.

Response from the Districts showed that the testers have helped indicate the degree and sometimes the cause of corrosion. Although little specific information about maintenance costs due to corrosion was available, most of the Districts agreed that there was a reduction in maintenance costs and trouble calls as a result of applying data derived from testers. As few Districts have used more than one tester, no comparison could be made as to which tester was best.

CONCLUSIONS

1. The BuMines tester, Corrosometer or locally fabricated and evaluated nipple or coupon testers will give an adequate indication of the rate and magnitude of corrosion although facilities required for evaluating specimens may preclude the use of the latter type of tester.

2. Where it is desired to monitor the effects of corrosion inhibition treatment and/or to observe results of operational changes in less than 30 days, the Corrosometer type instrument is to be preferred. The other testers require a minimum of 30 days for a reliable answer.

3. An additional advantage of the BuMines tester is the fact that the cause of corrosion can often be determined by the type of corrosion such as pitting and channeling.

REFERENCE

1. A. A. Berk. "Use of Condensate-Corrosion Tester for the Survey of Return-Line Deterioration." Corrosion, Vol. 14, No. 3 (March 1958), pp 141-144.

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